MINOR WRITTEN PRELIM EXAM

Fall 2008

September 24, 2008
8:30 a.m. to 12:00 p.m.

Please answer all questions.

Start each answer on a new page.

In the upper right hand corner of each sheet you hand in, put your name and the problem number. Staple together all sheets for a given problem.

Insert your answers and this exam into the manila envelope supplied. The exam questions will be returned to you along with your answers after they have been graded.

The following are some helpful items:

$h = 6.625 \times 10^{-34}\ \mathrm{J \cdot s} = 4.134 \times 10^{-15}\ \mathrm{eV \cdot s}$

$e = 1.6 \times 10^{-19}\ \mathrm{C}$

$c = 3.0 \times 10^{8}\ \mathrm{m/s}$

$k_B = 1.38 \times 10^{-23}\ \mathrm{J/K}$

$\sigma = 5.67 \times 10^{-8}\ \mathrm{W/K^4 \cdot m^2}$

$\epsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F/m}$

$\mu_0 = 1.26 \times 10^{-6}\ \mathrm{H/m}$

$\sin(A \pm B) = \sin A \cos B \pm \cos A \sin B$

$\cos(A \pm B) = \cos A \cos B \mp \sin A \sin B$

$2\cos A \cos B = \cos(A - B) + \cos(A + B)$

$2\sin A \sin B = \cos(A - B) - \cos(A + B)$

$2\sin A \cos B = \sin(A + B) + \sin(A - B)$

$2\cos A \sin B = \sin(A + B) - \sin(A - B)$

$\sin 2A = 2\sin A \cos A$

$\cos 2A = 2\cos^2 A - 1$

$\cos 2A = 1 - 2\sin^2 A$

$\sinh x = \frac{1}{2}\left(e^x - e^{-x}\right)$

$\cosh x = \frac{1}{2}\left(e^x + e^{-x}\right)$

$\nabla(\phi + \psi) = \nabla\phi + \nabla\psi$

$\nabla\phi\psi = \phi\nabla\psi + \psi\nabla\phi$

$\nabla \cdot (\mathbf{F} + \mathbf{G}) = \nabla \cdot \mathbf{F} + \nabla \cdot \mathbf{G}$

$\nabla \times (\mathbf{F} + \mathbf{G}) = \nabla \times \mathbf{F} + \nabla \times \mathbf{G}$

$\nabla(\mathbf{F} \cdot \mathbf{G}) = (\mathbf{F} \cdot \nabla)\mathbf{G} + (\mathbf{G} \cdot \nabla)\mathbf{F} + \mathbf{F} \times (\nabla \times \mathbf{G}) + \mathbf{G} \times (\nabla \times \mathbf{F})$

$\nabla \cdot (\phi\mathbf{F}) = \phi(\nabla \cdot \mathbf{F}) + \mathbf{F} \cdot \nabla\phi$

$\nabla \cdot (\mathbf{F} \times \mathbf{G}) = \mathbf{G} \cdot \nabla \times \mathbf{F} - \mathbf{F} \cdot \nabla \times \mathbf{G}$

$\nabla \cdot (\nabla \times \mathbf{F}) = 0$

$\nabla \times (\phi\mathbf{F}) = \phi(\nabla \times \mathbf{F}) + \nabla\phi \times \mathbf{F}$

$\nabla \times (\mathbf{F} \times \mathbf{G}) = \mathbf{F}(\nabla \cdot \mathbf{G}) - \mathbf{G}(\nabla \cdot \mathbf{F}) + (\mathbf{G} \cdot \nabla)\mathbf{F} - (\mathbf{F} \cdot \nabla)\mathbf{G}$

$\nabla \times (\nabla \times \mathbf{F}) = \nabla(\nabla \cdot \mathbf{F}) - \nabla^2\mathbf{F}$

$\nabla \times \nabla\phi = 0$

$\oint_{\mathrm{S}} (\mathbf{F} \cdot \mathbf{n})\, da = \int_{\mathrm{V}} (\nabla \cdot \mathbf{F})\, d^3x$

$\oint_{\mathrm{C}} \mathbf{F} \cdot d\ell = \int_{\mathrm{S}} (\nabla \times \mathbf{F}) \cdot \mathbf{n}\, da$

$\oint_{\mathrm{S}} \phi\mathbf{n}\, da = \int_{\mathrm{V}} \nabla\phi\, d^3x$

$\oint_{\mathrm{S}} \mathbf{F}(\mathbf{G} \cdot \mathbf{n})\, da = \int_{\mathrm{V}} [\mathbf{F}(\nabla \cdot \mathbf{G}) + (\mathbf{G} \cdot \nabla)\mathbf{F}]\, d^3x$

$\oint_{\mathrm{S}} (\mathbf{n} \times \mathbf{F})\, da = \int_{\mathrm{V}} (\nabla \times \mathbf{F})\, d^3x$

Fall 2008 Comprehensive Exam
Opti507
Optics Minor

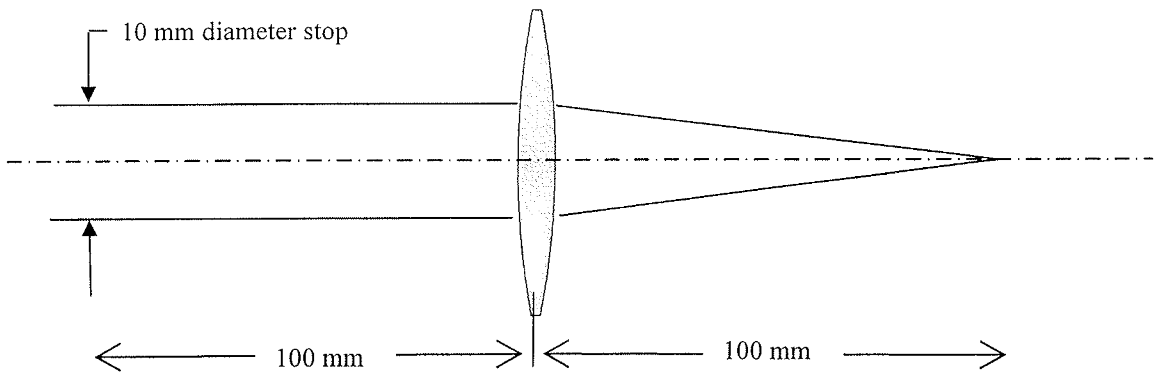
(a) (3 points) Consider a transition from a state in the valence band of a semiconductor with wave function $\psi_1(r)$ to a state in the conduction band with wave function ψ_2,(r), with ψ_1 and ψ_2 having well defined parities. Assume that the transition is dipole allowed with the interaction potential V(r) = -er. What should be the parities of the wave functions ψ_1 and ψ_2 for the transition to be allowed? Explain your answer.

(b) (4 points) Write down the energy and momentum conservation rules for exciton transitions in a semiconductor when the incident photon energy is $\hbar\omega$ and its momentum is $\hbar q$.

(c) (3 points) Using the angular momentum conservation rule for exciton transition in a semiconductor, determine the angular momentum of the exciton's envelope function.

Fall 2008 Comprehensive Exams
Opti509
Optics Minor

Consider a single thin lens made of SF57. The focal length of the lens for yellow (d – line) light is 100 mm. Assume an object point at infinity and a 10 mm stop, lens as shown below.
Parameters for the glass and definitions of the wavelengths are given in the tables below.



1. Draw a layout of the lens indicating where along the axis the yellow (d), blue (F), and red (C) light comes to focus. What is the spacing between the red and blue foci (15%)

2. Assume an image plane 100 mm from the lens, as shown. For an on-axis field point, Make sketches a) and b) showing the *chromatic* aberration (assuming other errors are corrected) for F, d, and C light for the case of on-axis imaging. Be sure to label your axes, including values.
   a) Ray fan diagram (transverse ray aberration *vs.* pupil coordinate) (20%)
   b) OPD diagram (wavefront aberration *vs.* pupil coordinate) (20%)

3. Evaluate the chromatic aberration for a field point 0.1 radians off axis. Sketch the following:
   a) Layout of the lens, showing the chief rays for F, d, and C (15%)
   b) Geometric point spread function for white light. Show approximate scale. (10%)
   c) Ray fan diagram (20%)

	SF57
refractive index n_d	1.847
Abbe number ν_d	23.8

n_d is refractive index at the d line, etc.

Abbe number is defined as $\upsilon_d = \dfrac{n_d - 1}{n_F - n_C}$

The F, d, and C lines occur at wavelengths:
$F: \lambda = 486.1$ nm
$d: \lambda = 587.6$ nm
$C: \lambda = 656.3$ nm

Fall 2008 Comprehensive Exam
Opti550
Optics Minor

A recently developed method of absolute-radiometric calibration is the solar-radiation-based approach. In this technique, the sun is used to illuminate a panel of known reflectance and the system to be calibrated measures the upwelling radiance from the panel. Compute the calibration equation relating voltage and radiance for a system calibrated using this approach and the following information:

- The system is linear and band-averaging has already been done
- System being calibrated has a center wavelength of 0.60 μm
- It is viewing a Lambertian panel at normal incidence
- The panel has a hemispheric reflectance of 0.95
- Exo-atmospheric solar irradiance is 1000 $W/m^2/\mu m$ at 0.60 μm
- Vertical molecular transmittance at 0.60 μm is 0.90
- Vertical aerosol transmittance at 0.60 μm is 0.85
- Solar zenith angle is 30 degrees
- Un-shaded system measurement is 9.50 Volts
- Shaded system measurement is 1.80 Volts
- The system reports 0.40 Volts when completely covered

Fall 2008 Comprehensive Exam
Opti587
Optics Minor

1. An optical detector used in a fiber communications system has the following properties: responsivity 0.40 A/W; detector capacitance 0.25 pF; load resistance 1 kΩ; T = 300°K. The fiber used in the system has an attenuation of 0.1 dB/km.

a. If 1.0 mW of optical power is launched into the fiber after what length of fiber will the shot noise equal the thermal noise of the receiver. Assume that the receiver is in a high impedance load configuration.

b. Now assume that 1.0 mW of signal power (`1' bit) is launched into 250 km of fiber and that the power in the `0' bit is 0 mW. Determine the BER at this position along the fiber. It can also be assumed that the noise is Gaussian.

c. Draw an `eye' diagram that corresponds to the results found in part `b'. Label the height of the `1' bit relative to the magnitude of the noise. Also label the bit period (limited by the bandwidth of the receiver) and show what the `eye' diagram looks like with a timing jitter that is 10% of the bit period.